



Influence of structural design variations on economic viability of offshore wind turbines: An interdisciplinary analysis



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ABSTRACT

Offshore wind energy is a seminal technology to achieve the goals set for renewable energy deployment. However, today's offshore wind energy projects are mostly not yet sufficiently competitive. The optimization of offshore wind turbine substructures with regard to costs and reliability is a promising approach to increase competitiveness. Today, interdisciplinary analyses considering sophisticated engineering models and their complex economic effects are not widespread. Existing approaches are deterministic. This research gap is addressed by combining an aero-elastic wind turbine model with an economic viability model for probabilistic investment analyses. The impact of different monopile designs on the stochastic cost-efficiency of an offshore wind farm is investigated. Monopiles are varied with regard to diameters and wall thicknesses creating designs with increased lifetimes but higher capital expenditures (durable designs) and vice versa (cheaper designs). For each substructure, the aero-elastic wind turbine model yields distributions for the fatigue lifetime and electricity yield and different capital expenditures, which are applied to the economic viability model. For other components, e.g. blades, constant lifetimes and costs are assumed. The results indicate that the gain of increased stochastic lifetimes exceeds the benefit of reduced initial costs, if the overall lifetime is not governed by other turbine components' lifetimes.

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1. Introduction

Although offshore wind energy is a steadily growing market [1] and a promising technology to achieve the long-term goals set for renewable energy deployment, its LCOE is still high compared to other energy supply types [2,3]. Today, OW energy is - apart from some rare and special examples - not yet competitive without financial support mechanisms [4], as compensation according to current electricity market prices does not enable a profitable and financially viable construction and operation of OW farms. Consequently, increasing the cost-efficiency of this technology is one of the major objectives of current research. As OWT substructures and foundations account for nearly 20% of the overall OW farm CAPEX (including planning, installation, and component costs, but excluding OPEX) and represent a significant cost reduction opportunity [2,5], their optimal design with regard to costs and reliability

is a promising approach. This means that a change in paradigm for optimal designs is required. In contrast to state-of-the-art optimization approaches, not only costs need to be minimized, but the trade-off between variable lifetimes and component costs needs to be analyzed in interdisciplinary approaches to find the most cost-efficient structural design. Nevertheless, such interdisciplinary approaches, considering both the complex engineering and economic aspects of OWT structural designs, are still unusual.

On the part of engineering analyses, most optimization approaches minimize the structural weight as a cost indicator [6–9]. Muskulus and Schafhirt [10] give a comprehensive review of these optimization approaches. Even if cost models are applied instead of mass considerations, the costs are, in general, approximated by empirical formulations taking into account material, production, and installation costs [11,12]. The effects of reduced masses or costs on the economic viability of entire projects are not evaluated, as economic aspects, like risk-adjusted discount rates, etc., are not taken into account. Furthermore, lifetimes are set to deterministic, constant values. This disables an analysis of the trade-off between

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